CHAPTER 3
HAZARD SUMMARY

This chapter describes possible health, environmental, and safety concerns related to clothes cleaning processes and the chemicals used therein. It highlights some of the issues related to these chemicals, but it is not intended to represent the full range of hazards that could be associated with clothes cleaning technologies.

CHAPTER CONTENTS

The chapter provides data on each of the technologies and the individual chemicals used within those technologies as defined by this Cleaner Technologies Substitutes Assessment (CTSA). For each technology and/or chemical, the chapter presents summaries of human health and toxicological data, including exposure routes; toxicity endpoints (e.g., carcinogenicity, developmental toxicity, and neurologic effects); and hazard measures. More detailed discussions of the studies are presented in Appendix C. Environmental effects data on acute and chronic aquatic toxicity levels for fish, invertebrates, and algae and environmental hazard rankings for individual chemicals are included. The chapter also describes safety hazards that may be associated with the various technologies or chemicals.

3.1 INTRODUCTION

In understanding how the choice of alternative technologies may affect humans and the environment, it is important to consider the effects that could result from exposure to the clothes cleaning processes and the chemicals used in the various technologies under a specified set of conditions. Effects can relate to health and well-being, such as the ability of a chemical to cause cancer or respiratory illness. They can also be environmental in nature, such as the ability of a chemical to cause harm to aquatic organisms. These effects on human health and the environment are often described as the hazard associated with the chemicals and technologies. In its description of the potential hazards associated with the alternative fabricare technologies, the CTSA includes effects on physical property, such as those related to flammability

The chemistry and environmental fate of a substance also play important roles in determining both hazard and potential exposure. Appendix A provides the chemical/physical properties of each chemical and environmental fate summaries for some of the chemicals considered in the CTSA.

The data presented on chemical hazards focus on individual chemicals. Some technologies employ mixtures of chemicals or formulations. Examples include machine wetcleaning and hydrocarbon (HC) solvents. Ingredients (or components) of the formulations may differ from manufacturer to manufacturer or supplier to supplier. While information on the specific formulation would be preferable, it is not generally available. This section provides hazard data for chemicals among those typically used as components.

Certain hazards, common to all technologies, are not expected to be noticeably different across technologies. For instance, there are hazards of physical injury associated with the ergonomic environment of the fabricare operation. Fabricare requires that employees perform a variety of tasks, some to operate the cleaning equipment, some to carry out associated activities (e.g., pressing, clothes bagging). The highly repetitive nature of these tasks can generate musculoskeletal injury. In particular, shops where garment transfer is required entail such tasks as (1) moving carts with soiled items, (2) loading the washer, (3) unloading the washer/extractor and loading the reclaimer or dryer, (4) setting controls and turning on each machine, (5) sorting dried items for presser designations, and (6) moving dried items to a pressing area. These tasks are largely comprised of lifting and bending stresses. (Terminology and machine functions involved in transfer may differ from technology to technology; for instance, the machine wetcleaning process or a perchloroethylene (PCE) dry-to-dry machine may not require task 3.) Adding a hamper enclosure to a PCE operation to control fugitive emissions may increase lifting stress, through increasing the horizontal distance from the spine to the lifting activity of the hands, the most critical measurement in the multiplicative National Institute for Occupational Safety and Health (NIOSH) "lifting equation" for repetitive stress injuries (Waters et al., 1994). Because such injuries are more a function of the specific fabricare operation than the technology used, they are not examined further in the CTSA.

3.2 OVERALL SUMMARY

3.2.1 Human Health Hazard

Approach

The CTSA is intended to compile existing information on potential health effects resulting from exposures to clothes cleaning technologies. Literature searches were limited to such sources as USEPA's Integrated Risk Information System (IRIS), the National Library of Medicine's Hazardous Substances Data Bank (HSDB), TOXLINE, TOXLIT, GENETOX, and the Registry of Toxic Effects of Chemical Substances (RTECS). These sources are considered to be secondary sources, and a minimal attempt was made to verify the information contained therein. Additionally, toxicologic data developed under the Chemical Testing Program of USEPA's Office of Pollution Prevention and Toxics (OPPT), where available, are incorporated in the human health hazard summaries.

Results

Exhibit 3-1 summarizes human health effects information obtained to date on chemicals used in the clothes cleaning industry. Later sections in the chapter provide a brief summary for each technology and the chemicals used within that technology.

The "Toxicity Endpoint" column in Exhibit 3-1 lists adverse toxicological effects by expected exposure routes reported in the literature for animal or human studies. This is simply a qualitative listing of reported observed effects. The list does not imply anything about the severity of the effects, nor the doses at which the effects occur. Furthermore, an entry in this column does not necessarily imply that USEPA has critically reviewed the reported studies or that USEPA concurs with the authors' conclusions.

Exhibit 3-1. Human Health Hazard Summary[a]

Chemical Name	CAS No.	Expected Exposure Route	Toxicity Endpoint
Drycleaning Technology - Perchloroethylene			
Perchloroethylene[b]	127-18-4	Inhalation, dermal, oral	Liver and kidney toxicity, neurotoxicity, developmental and reproductive toxicity, and cancer.
Drycleaning Technology - Hydrocarbon Solvents			
Stoddard solvent (petroleum)[b,c]	8052-41-3	Inhalation, dermal	Irritation of the eye, skin, and respiratory tract, and neurotoxicity.
Machine Wetcleaning Technology - Detergent Component Examples[d]			
Surfactants			
Cellulose gum	9004-32-4	Dermal, inhalation	No significant adverse effects noted in animal and human studies.
Cocamidopropyl betaine	61789-40-0	Dermal, inhalation	Possible eye and skin irritant.
Ethoxylated sorbitan monodecanoate	9005-64-5	Dermal	Little or no skin irritation. May enhance tumor activity of carcinogenic compounds.
Lauric acid diethanolamide	120-40-1	Inhalation, dermal	Mild eye irritant.
Sodium laureth sulfate	9004-82-4	Dermal	Eye and skin irritant.
Sodium lauryl isethionate	7381-01-3	Dermal	Limited information suggests may not be an irritant.
Surfactant Aids			
Acetic acid	64-19-7	Inhalation, dermal	Eye injury.
Citric acid and sodium citrate	77-92-9 68-04-2	Inhalation, dermal	Eye and skin irritant.
Sodium carbonate	497-19-8	Inhalation, dermal	Eye and skin irritation; respiratory effects.

[a] Technical hazard summaries may be found in Appendix C. Hazards represent possible effects identified and do not indicate the likelihood of the effect occuring.
[b] Refer to Appendix D for a discussion of the doses used in the risk assessment (Chapter 5).
[c] Stoddard solvent hazard data are assumed to be representative for other hydrocarbon solvents (140°F solvent and DF-2000).
[d] Chemicals are based upon an example detergent formulation developed for presentation in the CTSA. Therefore, it is not clear how representative they may be of chemicals used in actual detergent formulations.

In the sections that follow, the most salient human health hazards associated with individual chemicals within each technology are summarized. The information includes route(s) of exposure, absorption and metabolism, human and animal toxicity information, irritation and sensitization potential, and carcinogenic potential. These sections represent brief summaries of applicable information. Appendix C contains a more detailed review of the hazard summaries for many of these chemicals, including citations and references. Appendix D contains the dose-response assessments for PCE and hydrcarbon (HC) solvents, which are used in the risk assessment (Chapter 5).

3.2.2 Environmental Hazard

Approach

The environmental hazard assessment of chemicals identifies effects that a chemical may have on organisms in the environment. An overview of this assessment process has been reported by Zeeman and Gilford (1993) and is summarized in Appendix B. The effects are expressed in terms of the toxicity of a chemical on the organisms and are generally given as the effective concentration (EC) that describes the type and seriousness of the effect for a known concentration of a chemical. A Hazard Profile or Toxicity Profile is created when the ECs for a range of species are tabulated for a chemical. A detailed discussion of a prototypic comprehensive Hazard Profile has been presented by Nabholz (1991).

The most frequently used Hazard Profile for the aquatic environment consists of three chronic and three acute effective concentrations as reported by Nabholz, et al. (1993). These are:

- A fish acute value (usually a fish 96-hour LC_{50} value) where LC_{50} represents the concentration that is lethal to 50 % of the tested organisms at the end of the exposure period;
- An aquatic invertebrate acute value (usually a daphnid 48-hour LC_{50} value);
- A green algal toxicity value (usually an algal 96-hour EC_{50} value) where EC_{50} represents the concentration at which a chemical inhibits algal growth (biomass) by 50% at the end of the exposure period;
- A fish chronic value (Chapter 5), calculated according to Nabholz et al. [1993]), which is often obtained from a fish 28-day early life stage study;
- An aquatic invertebrate chronic value (usually from a daphnid 21-day study); and
- An algal chronic value (usually from an algal 96-hour study for biomass).

USEPA obtained the ecological/environmental toxicity values used in the Hazard Profile from the results of standard toxicity tests reported to USEPA or published in the literature (i.e., measured values) or estimated them based upon Structure-Activity Relationships (SARs) (predictive equations). SARs are based on the assumption that chemicals with similar structural features will show similar toxic effects, and they use data from many chemicals to predict these effects.

For the CTSA, USEPA assessed discrete organic chemicals using predictive SAR equations. USEPA found no data that conflicted with these estimates; however, few of the specific chemicals, with the exception of PCE and Stoddard solvent, have studies reported.

Some products, such as detergents, softeners, surfactants, and hydrocarbon solvents are mixtures and do not lend themselves readily to the standard hazard assessment process using SARs. USEPA therefore evaluated the machine wetcleaning detergent formulations on a per constituent basis for this CTSA. Thus, the toxicity values are for the discrete chemical only; interactions between chemicals within a formulation are not considered.

Upon completion of a hazard profile, USEPA determined a concern concentration (CC). A CC is the concentration of a chemical in the aquatic environment that if exceeded, may result in a significant risk. Conversely, if the CC is not exceeded, it is assumed that the probability of a significant risk occurring is low. The CC for each chemical is determined by applying assessment factors (USEPA, 1984) to the effect concentrations in the Hazard Profile.

After assigning a CC, USEPA ranked chemicals according to hazard concern levels for the aquatic environment. This ranking can be based upon the acute toxicity values expressed in milligrams per liter (mg/L). The generally accepted scoring is as follows (Clements et al., 1993):

High Acute Concern (H)		≤ 1
Moderate Concern (M)	> 1 and	< 100
Low Concern (L)		> 100

This ranking can also be expressed in terms of chronic values as follows:

High Chronic Concern (H)		≤ 0.1
Moderate Concern (M)	> 0.1 and	< 10.0
Low Concern (L)		≥ 10.0

The chronic toxicity ranking takes precedence over the acute ranking.

Results

The results of the estimated aquatic toxicity determinations are summarized in Exhibit 3-2. For each chemical, the exhibit gives the estimated toxicity values in mg/L (ppm) for acute and chronic effects of fish, daphnid, and algae. The second-to-last column shows the CC set for the chemical in water. The last column notes the hazard rank using the method described above.

Exhibit 3-2. Estimated Aquatic Toxicity Values of Dry and Wetcleaning Chemicals Based on Measured Data and Struture Activity Relationship (SAR) Analysis (mg/L)[a]

Chemical Name	CAS Number	Acute Toxicity (mg/L)			Chronic Toxicity (mg/L)			Concern Conc. (mg/L)[b]	Hazard Rank
		Fish	Daphnid	Algal	Fish	Daphnid	Algal		
Drycleaning Technology - Perchloroethylene									
PCE (SAR)	127-18-4	5.9	7.0	4.8	0.96	0.66	1.07	0.07	moderate
PCE (measured data)	127-18-4	5	8.5	--	2.3	0.51	--	0.05	moderate
Drycleaning Technology - Hydrocarbon Solvents[c]									
Stoddard solvent (SAR)	8052-41-3	0.14	0.19	0.14	0.005	0.006	0.015	<0.001	high
Stoddard solvent (measured data)	8052-41-3	2.1	0.42	--	--	--	--	0.004	high
Machine Wetcleaning Technology - Detergent Component Examples									
Acetic acid (SAR)	64-19-7	>100	>100	>100	>10	>10	>10	>1	low[d]
Cellulose gum[e] (SAR)	9004-32-4	--	--	--	--	--	--	--	--
Citric acid (SAR)	77-92-9	>100	>100	5	>10	>10	1/30[f]	0.1/3[f]	moderate/ low[f]
Cocamidopropyl betaine (SAR)	61789-40-0	>10	>10	>10	>10	>10	>10	0.2	moderate
Ethoxylated sorbitan monodecanoate (SAR)	9005-64-5	20	20	20	3	3	3	0.3	moderate
Lauric acid diethanolamide (SAR)	120-40-1	6	6	6	0.6	0.6	1	0.06	high
Methyl 2-sulfolaurate, sodium salt (SAR)	4337-75-1	20	15	15	3.0	2.3	3.7	0.2	moderate
Sodium carbonate (SAR)	497-19-8	8300	2400	240	>100	>100	>60	6	moderate
Sodium laureth sulfate (SAR)	9004-82-4	40	30	30	6.2	4.6	8.0	0.46	moderate
Sodium lauryl isethionate (SAR)	7381-01-3	10	10	>10	2	2	3	0.2	moderate

[a] Aquatic toxicity values based on the use of SARs except where noted.
[b] Concern Concentration (CC) is derived by dividing the lowest chronic value by ten. If result is < 0.001 then CC is set at 0.001.
[c] For the CTSA, toxicity levels, concern concentrations, and hazard rankings for 140°F solvent and DF-2000 are assumed to be the same as presented for Stoddard solvent (SAR).
[d] The hazard ranking for acetic acid should be low because after treatment the chemical will be relased at pH 7. At this pH the chemical is neutral without acid reaction.
[e] Indicates that toxic effects are not expected in a saturated solution during the prescribed exposure period of a standard test.
[f] Algae are particularly sensitive to citric acid. The first value represents predicted toxicity and concern for normal water hardness and the second for moderately hard water.

3.3 HAZARD SUMMARIES BY TECHNOLOGY

3.3.1 Drycleaning Technologies

The review of drycleaning hazards focuses primarily on the use of non-aqueous solvents (PCE and HC solvents), and does not cover spotting chemicals, fabric finishes, water softeners, and detergents that may also be used in the process.

Perchloroethylene

PCE Health Hazard Summary

The majority of information summarized below comes from secondary sources (USEPA, 1985; ATSDR, 1993). Refer to Appendix C for more detailed information.

Studies in laboratory animals have shown that PCE is quickly absorbed by the body after ingestion. In addition, PCE vapor in the air can be rapidly absorbed into the body through the lungs. PCE can be absorbed into the body through the skin; although the absorption via the skin is approximately equal to inhalation at low exposures (410 mg/m^3), it can be as low as 1% of the amount absorbed via inhalation at higher exposures (4,100 mg/m^3). Most of the PCE that is absorbed into the body rapidly leaves, unchanged, in the exhaled air. However, PCE that remains in the body changes into other substances. These other substances are thought to be responsible for many of the adverse health effects attributed to PCE.

People who breathe air that contains PCE for a short time may experience short-term effects on the nervous system that are suggestive of depressed brain activity. The effects range from altered electrical activity in the brain at moderate levels to dizziness, drowsiness, lack of coordination, faintness, headache, and nausea at higher levels and collapse, seizures, coma, and death at still higher levels. The effects on the nervous system gradually fade when the affected person is removed from the contaminated air. Drycleaning personnel who were exposed to low (<350 mg/m^3) concentrations of PCE in the air for three or more years did not perform well on neurobehavioral tests. Studies in laboratory animals have shown that large doses of PCE taken by mouth or inhaled can produce lack of coordination, tremors, narcosis, and death. It is not known if PCE can produce effects on the nervous system by skin contact.

People who breathe air that contains PCE may also have liver and kidney dysfunction. These effects are most strongly associated with short-term exposure to high PCE levels in humans, but mild kidney and liver dysfunction has also been reported from long-term exposure to PCE. In support of findings in humans, studies in laboratory animals have shown that PCE damages both the liver and kidneys. These effects occur regardless of whether PCE is inhaled or taken by mouth and can occur either from short-term exposure to high levels or long-term exposure to lower levels.

The International Agency for Research on Cancer (IARC) recently concluded that PCE is probably carcinogenic to humans based on studies in laboratory animals and human epidemiological studies (IARC, 1995). Male and female mice that breathed air containing PCE or ingested PCE for most of their lifetime developed liver tumors. In addition, rats that breathed air containing PCE for most of their lifetime

appeared to have increased rates of leukemia (males and females) and kidney tumors (males only). It is not clear, however, if the tumors that developed in these animals are relevant to humans. Workers exposed to PCE for many years showed increased rates of esophageal cancer. The significance of this finding is limited, however, due to weaknesses in the study. PCE has not been shown to interact strongly with genetic material, but several of the substances produced from PCE in the body have been shown to do so.

It is not known if PCE produces birth defects or interferes with reproduction in humans. Some studies of workers exposed to PCE in the drycleaning industry have reported findings suggesting that such effects occur, but these studies have many limitations that hinder their interpretation. Studies in laboratory animals indicate that PCE produces effects on the developing fetus that include altered growth, birth defects, and death. Exposure of rats to PCE for three consecutive generations resulted in an increased number of stillborn young, decreased litter sizes and survival of the young, and decreased testis weight in males.

The hazard values to be used in the risk assessment (Chapter 5) are a cancer inhalation unit risk value of 7.1×10^{-7} per $\mu g/m^3$ (for use only with exposures below 1.4×10^4 $\mu g/m^3$) and a provisional RfC of 0.17 mg/m^3 (see appendix D for details). The oral values are a cancer slope factor of 0.051 per mg/kg/day (for use only with exposures below 2×10^{-1} mg/kg/day) and an RfD of 0.01 mg/kg/day.

PCE Environmental Hazard Summary

The results of the hazard profile are summarized in Exhibit 3-2. The acute toxicity values for fish obtained from the AQUIRE database range from 13.4 to 21.4 mg/L with a geometric mean of 16.1 mg/L (11 tests) (USEPA, 1994). USEPA did not critically review the studies from the AQUIRE database to determine the validity of the test results reported.

A recent review of PCE toxicity to aquatic species was reported by the United Kingdom (SIAR, 1996). Valid acute toxicity data were reported for rainbow trout (96-hour LC_{50} of 5 mg/L) and daphnids (48-hour LC_{50} of 8.5 mg/L). Valid chronic toxicity data were also reported for fish (28-day no-observed-effect concentration [NOEC] of 2.34 mg/L) and daphnids (28-day NOEC of 0.510 mg/L).

The lowest reported measured NOEC was 0.510 mg/L in a daphnid 28-day study (Richter et al, 1983, as cited in SIAR, 1996). The estimated acute toxicity values for PCE are 5.9, 7.0, and 4.8 mg/L for fish, daphnid and algae, respectively. The estimated acute value for fish of 5.9 mg/L is within a factor of 2.5 of the mean AQUIRE value of 16.1 and is similar to the value of 5 mg/L reported in SIAR (1996). The estimated chronic values for fish, daphnid, and algae are 0.96, 0.66, and 1.07 mg/L, respectively. PCE is of moderate concern for chronic effects to aquatic organisms (equal or greater to 0.1 and less than or equal to 10 mg/L). The overall ranking of PCE based on chronic concerns is included in Exhibit 3-2.

Hydrocarbon Solvents

The hazard summaries for hydrocarbon solvents focus on the solvents used in drycleaning, which are mixtures of linear, branched, and cyclic carbon compounds that have different chemical/physical characteristics. Health data were predominately found for Stoddard solvent (ATSDR, 1995); however, it is believed that the other hydrocarbon solvents, 140°F solvent and DF-2000, would have similar health

concerns. This is also true for the description of the environmental hazards of these solvents. Differences are expected, however, in flammability hazards, and these differences are noted.

Hydrocarbon Solvents Health Hazard Summary

It is not known to what extent Stoddard solvent taken by mouth will be absorbed, but comparisons to other petroleum products suggest that at least some of the substances that make up Stoddard solvent can be absorbed into the body through the gut. Stoddard solvent vapor or mist in the air is quickly absorbed into the body through the lungs. Stoddard solvent can also be absorbed into the body through the skin. Stoddard solvent that is absorbed by the body collects in body fat, but over time, it is gradually released from the fat and leaves the body. While in the body, some of the substances that make up the solvent can be changed to other substances by the body's metabolism. It is not known how much of the solvent is changed in this way, nor is much known about the nature of these changes.

Stoddard solvent in the air may be irritating to the eyes, nose, throat, and other moist exposed skin. At moderate levels, comparable to those at which workers are typically exposed, irritation is slight and few people are affected. At higher levels, the irritation becomes stronger and more people are affected. Studies in laboratory animals have shown that liquid Stoddard solvent applied directly to the skin produces moderate skin irritation. In one known case a worker whose skin was in contact with Stoddard solvent developed an allergic skin reaction.

People who breathe air containing Stoddard solvent or whose skin comes into contact with Stoddard solvent may also experience effects on the nervous system. In an experiment, volunteers who breathed air containing high levels of Stoddard solvent for a short period did not perform as well on nervous system tests, which measured reaction time and short-term memory, as people who had not been exposed. Workers exposed to Stoddard solvent have reported headaches, lightheadedness, fatigue, decreased color discrimination, and memory impairment. However, many of these workers were also exposed to other substances at home and work that could have contributed to these effects. Laboratory animals exposed to very high levels of Stoddard solvent in the air showed effects ranging from slowed reactions and incoordination to tremors, convulsions, and death. The levels that produced these effects were more than 10 times the levels to which workers are typically exposed.

It is not known if Stoddard solvent can produce cancer; the available studies in humans and animals were inconclusive. Stoddard solvent has not, however, been shown to interact with genetic material in short-term mutagenicity tests. It is also not known if Stoddard solvent can produce birth defects or interfere with reproduction in humans. Limited studies in laboratory animals have not shown that Stoddard solvent can produce these effects.

The hazard value to be used in the risk assessment (Chapter 5) is a NOAEL (no-observed-adverse-effect level) of 480 mg/m^3 (see Appendix D for details).

Hydrocarbon Solvents Environmental Hazard Summary

A search of the AQUIRE database for aquatic toxicity of Stoddard solvent and 140°F solvents yielded no information (USEPA, 1994). The World Health Organization (WHO) recently published an

Environmental Health Criteria document on Stoddard solvent (WHO, 1996). Limited aquatic toxicity data (acute only) show a range of both daphnid 48-hour LC_{50}s (0.42 to 2.3 mg/L) and fish 96-hour LC_{50} values (2-21 mg/L) under a variety of test conditions.

USEPA assessed the chemicals using SARs to estimate the inherent toxicity of these chemicals to aquatic organisms. The chemicals belong to the chemical class "neutral organics," for which there are predictive equations for estimating three acute and three chronic values. Hydrocarbon solvents are mixtures; the chemical constituents and the percentage of each in the hydrocarbon solvent mixture varies. The standard hazard assessment process using SARs is not appropriate for mixtures such as these, and therefore USEPA evaluated them in a slightly different manner. The constituents in these products include linear hydrocarbons and cyclic hydrocarbons, with the total number of carbons varying between 9 and 12. To measure the toxicity of the solvents, USEPA estimated the toxicity of each individual constituent and then evaluated the potential hazard of the product.

The estimated chronic toxicity values for the individual components (i.e., C_9 to C_{12} linear hydrocarbons and cyclic hydrocarbons) are given in Exhibit 3-3. Acute toxicity data could only be predicted for 9-carbon cyclic compounds (0.14, 0.19, and 0.14 mg /L for fish, daphnid, and algae, respectively); 10- and 11-carbon cyclic compounds (algae only, 0.04 and 0.02 mg/L, respectively); and for 9- and 10-carbon linear/branched compounds (algae only, 0.06 and 0.02 mg/L, respectively). To estimate the toxicity, the geometric mean of the predicted values was calculated. The geometric mean of estimated chronic values for fish, daphnids, and algae range from 0.005 to 0.028 mg/L, which constitutes a high concern for chronic effects.

Measured acute toxicity data for Stoddard solvent suggest chronic values of 0.04 mg/L for daphnids and 0.2 mg/L for fish. These are within a factor of 10 of the predicted acute toxicity values. Using either the measured or predicted values, there is a high concern to aquatic organisms.

Hydrocarbon Solvents Flammability Hazard

The NFPA (19xx) Fire Protection Guide to Hazardous Materials (10th edition) of the National Fire Protection Association (NFPA) ranks chemicals on a scale of 0 through 4 for flammability. Materials ranked 0 will not burn, and those ranked 4 include flammable gases, pyrophoric liquids, and flammable liquids. All of the hydrocarbon solvents covered in the CTSA are ranked 2, meaning that they must be moderately heated before ignition will occur and that they readily give off ignitable vapors.

Stoddard solvent is also considered ignitable based upon the standard outlined in 40 CFR §261.20 (Protection of the Environment, RCRA; Identification and Listing of Hazardous Waste, Characteristic of Ignitability). Under this standard, a chemical is considered ignitable if it "is a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume and has a flash point less than 60°C." DF-2000 and 140°F solvent are considered to have a non-ignitable ranking.

Exhibit 3-3. Estimated Chronic Toxicity Values (mg/L) for Linear, Branched, and Cyclic Hydrocarbon Solvents[a]

Type of Molecule	No. of Carbons	Est. Log K_{ow}[b]	Fish Chronic Value	Daphnid Chronic Value	Algal Chronic Value
Linear or Branched	9	5.4	0.013	0.019	0.045
	10	6.0	0.004	0.008	0.021
	11	6.5	0.002	0.004	0.011
	12	7.0	None[c]	0.002	0.005
Geometric Mean			**0.005**	**0.006**	**0.015**
Cyclic	9	5.0	0.03	0.04	0.08
	10	5.6	0.01	0.02	0.04
	11	6.1	0.004	0.007	0.02
	12	6.7	0.001	0.003	0.009
Geometric Mean			**0.006**	**0.011**	**0.028**

[a] Estimates derived from SAR equation for neutral organics using number of carbons and $LogK_{ow}$.
[b] Estimated $LogK_{ow}$ (octanol-water partition coefficient) taken from CLOGP Version 3.3 Program (Leo and Weininger, 1985).
[c] No effects expected in a saturated solution during the prescribed exposure period.

Data were not available to assess the potential for the hydrocarbon solvents to ignite and cause a fire incident. A search of the NFPA Fire Incident Database Organization for articles published in the *NFPA Journal* about incidents in drycleaning facilities in which Class II (flammability) combustible liquids were first ignited resulted in no identified incidents (Ahrens, 1998). Fire potential is a commonly recognized hazard of hydrocarbon solvents; however, the significance of that potential or of the differences in potential among the three hydrocarbon solvents is not addressed in this CTSA.

3.3.2 Machine Wetcleaning Technology

Machine wetcleaning detergent formulations are complex mixtures typically containing water and a variety of other different chemicals. Most formulations are trade secrets, and the concentrations of the individual chemicals are unknown to all but the manufacturer. The CTSA bases exposure estimates on two example detergent formulations developed for presentation in the CTSA (see Chapter 4 and Appendix E). Detergent #1 contains 10 constituents (plus water), and Detergent #2 contains 12 constituents (plus water). Seven constituents are common to both formulations, three are unique to Detergent #1, and five are unique to Detergent #2. It is not known how representative these chemicals are of those found in actual detergent formulations.

Health hazard summaries are presented for 10 of the 15 constituents found in the example detergents used in this CTSA. Hazard summaries are not provided for lauryl polyglucose, Aveda's fragrance, cocamphocarboxyproprionate, diazolidinyl urea, and methyl-2-sulfolaurate. Environmental hazard summaries are based upon SAR estimates. The summaries are designed to illustrate the potential range of effects that are associated with surfactant and surfactant aids that are found in machine wetcleaning detergents. The representativeness of these effects for actual formulations in not known. Some environmentally desirable chemical characteristics pertain to a number of different detergent components and may help guide those evaluating detergents.

Typically, the environmental profile of a chemical improves with its rate of biodegradation. However, it is equally important to consider the byproducts formed by the degradation process. These products can be more toxic than the parent compound.

Certain type of polymers have less potential to harm the environment than others. Nonionic (negatively charged) polymers are generally the least aquatically toxic; cationic (positively charged) polymers tend to have higher acute toxicity to aquatic organisms.

Generally, the potential for a molecule to be absorbed and harm an organism is lower the larger the molecule. Also, molecules that have straight carbon chains present less environmental concerns than those that are highly branched and tend to resist biodegradation.

The chemicals in the detergents considered in this hazard summary can be grouped into surfactants and surfactant aids. Surfactants are used to reduce the surface tension of water so that it may more thoroughly wet the surface to be cleaned (Soap and Detergent Association, 1998) and are the primary chemicals found in the example detergent formulation reviewed for this document. Surfactant aids may enhance the functions of the surfactants and can include components such as soil suspenders, pH adjusters, and solubilizers.

The CTSA examines the human health and environmental hazards of surfactants because they are the primary components of most detergents. In general, there are several characteristics of surfactants that may affect the degree to which human health and environmental effects are likely. These chemicals can differ in inherent toxicity, persistence, and bioaccumulation potential, any of which can be a concern. Surfactants that minimize these characteristics are presumed to be more desirable. A desirable property of surfactants is that they can be easily destroyed, either through conventional treatment processes or through biodegradation. Those that are easily destroyed are less likely to be persistent in the environment. For instance, linear alcohol ethoxylates (LAEs) biodegrade to linear alcohols and carboxylic acids, compounds of low environmental concern; alkylphenol ethoxylates, in contrast, may biodegrade under anaerobic conditions to alkylphenols, which persist in the environment and may be highly toxic to aquatic organisms. Also, LAEs are soluble in colder water and so may aid in the development of low temperature, energy-saving detergents.

The following are chemical specific hazard summaries for several surfactants included in the CTSA's example formulations, provided for illustrative purposes.

Surfactants

Cellulose Gum

Cellulose Gum Health Hazard Summary

The information in this summary is taken from CIR (1986a).

Cellulose gum does not appear to be absorbed into the body from the gut or through the lungs or skin and has been shown to be excreted entirely in the feces. The likelihood that exposure to cellulose gum would cause health effects is very low.

Cellulose gum has not been found irritating to the skin, lung, or eyes. Cellulose gum applied to the skin of humans does not appear to be irritating or to produce an allergic reaction. In a few studies, irritation was noted, but it was classified as mild at the worst. Repeated application of cellulose gum to the skin of laboratory animals caused only slight irritation and only in a few animals. Minimal or no eye irritation was noted in laboratory animals given various cosmetic products containing cellulose gum.

No adverse effects were found in people who swallowed cellulose gum regularly over a period of six months to three years. Studies with a variety of laboratory animals have shown that ingestion of large quantities of cellulose gum daily for several months did not cause any changes in behavior or other adverse effects. Similarly, inhalation of cellulose dust has not been shown to cause any toxic effects in exposed workers.

Laboratory animals given cellulose gum by mouth have shown no evidence of birth defects or interference with reproduction. Cellulose gum has been found not to interact with genetic material. There have been no carcinogenicity studies reported for cellulose gum.

Cellulose Gum Environmental Hazard Summary

The environmental hazard summary for cellulose gum is based on the SAR method described above and in Appendix B. Results for cellulose gum (Exhibit 3-2) suggest that it does not warrant concern as a hazard to the aquatic environment.

Cocamidopropyl Betaine (CAPB)

CAPB Health Hazard Summary

The information in this summary is taken from CIR (1991).

It is not known how readily CAPB is absorbed into the body through the gut, lungs, or skin, or how easily the body can change it to other substances or excrete it. Available information suggests that for humans, the most likely route of exposure to CAPB is through the skin.

For humans, CAPB has been found to cause skin irritation. Exposure of human skin to a soap formulation containing CAPB for several consecutive days produced minimal skin irritation, whereas longer exposure produced more severe irritation. In laboratory animals, skin application of CAPB solutions produced a range of irritation reactions, from no reaction to severe irritation, depending on the percentage of CAPB in the solution tested. Allergic reactions were not found in humans whose skin was exposed to several different formulations of CAPB. Several instances of apparent contact dermatitis in humans exposed to consumer products that contain CAPB have been reported, but recent evidence suggests that the major cause of this reaction is a different chemical present in the detergent formulation. Laboratory animals whose skin was exposed to CAPB have shown no or slight allergic responses. CAPB is potentially irritating to the eye. Laboratory animals exposed to varying concentrations of CAPB exhibited swollen eyelids and mild to moderate corneal irritation.

It is not known how long-term exposure to CAPB through ingestion, inhalation, or skin contact affects humans. When ingested by laboratory animals, CAPB does not appear to cause any serious health effects. Animals ingesting a single large dose or several doses of CAPB for one month exhibited only stomach or intestinal irritation. Moreover, when CAPB was applied to the skin of laboratory animals several times a week for 20 months, no serious health effects were observed.

There is no information on whether CAPB can affect the nervous system, interfere with reproduction, or produce birth defects. CAPB has not been found to interact with genetic material in short-term mutagenicity tests. There is no evidence that CAPB can cause cancer. CAPB was not carcinogenic in a mouse skin-painting study.

CAPB Environmental Hazard Summary

The environmental hazard summary for CAPB is based on the SAR method described above and in Appendix B. Results for CAPB (Exhibit 3-2) suggests that it warrants a moderate level of concern as a hazard to the aquatic environment.

Ethoxylated Sorbitan Monodecanoate

Ethoxylated Sorbitan Monodecanoate Health Hazard Summary

The information in this summary is taken from CIR (1984).

It is not known to what extent ethoxylated sorbitan monodecanoate (P-20) is absorbed into the body through the gut, lungs, or skin. If P-20 enters the body, it is broken down by the body. The fatty acid portion of the broken down substance remains in the body, is readily absorbed, and is broken down further to yield energy for important life processes. The remaining portion of the substance is poorly absorbed by body tissues and leaves the body unchanged. The most likely routes of exposure are by mouth and by skin contact. There is very little likelihood of inhalation exposure to P-20.

Skin contact with P-20 may cause little or no irritation in humans or animals. No evidence of allergic skin reactions was found in people whose skin had previously been in contact with P-20. However,

skin exposure of laboratory animals to P-20 produced moderate to strong allergic reactions. In laboratory animals, P-20 produced no or mild irritation when it came into contact with the eyes.

Low to moderate amounts of P-20, taken by mouth by humans or animals on one or more occasions, produced no deaths or adverse effects. However, an extremely high dose given over a long period of time produced damage to the kidneys, spleen, and gut in one species of laboratory animal. It is not known if adverse effects occur in people who breathe air containing dusts of P-20.

There is no information on whether P-20 can affect the nervous system, produce birth defects, or interfere with reproduction. Based upon findings for other similar polysorbates, P-20 is not expected to interact with genetic material. Although P-20 is not a cancer-causing substance itself, it has been shown to enhance the activity of known cancer-causing substances and to inhibit tumor growth activity under certain conditions.

Ethoxylated Sorbitan Monodecanoate Environmental Hazard Summary

The environmental hazard summary for ethoxylated sorbitan monodecanoate is based on the SAR method described above and in Appendix B. Results (Exhibit 3-2) suggest that ethoxylated sorbitan monodecanoate warrants a moderate level of concern as a hazard to the aquatic environment.

Lauric Acid Diethanolamide (Lauramide DEA)

Lauramide DEA Health Hazard Summary

The information in this summary is taken from CIR (1986b).

It is not known how readily lauramide DEA is absorbed into the body through the gut, lungs, or skin, or how easily the body can change it to other substances or excrete it.

Contact of human skin with lauramide DEA may cause skin irritation. Exposure of human or animal skin to soaps containing lauramide DEA for several consecutive days produced minimal to moderate skin irritation. The degree of irritation depended on the percentage of lauramide DEA in the soap product. Laboratory animals exposed to skin products containing up to 25% lauramide DEA daily for several months showed only minimal skin irritation. However, very high concentrations of lauramide DEA caused severe skin irritation. Allergic reactions were not found in humans whose skin had been exposed to products containing lauramide DEA.

Lauramide DEA is irritating and potentially damaging to the eyes. Exposure of the eyes of laboratory animals to a low (1%) concentration of lauramide DEA produced only slight, temporary eye irritation. A moderate (5%) concentration of lauramide DEA produced moderate eye irritation, whereas a high (25%) concentration produced severe eye irritation and permanent damage in laboratory animals.

When lauramide DEA is taken by mouth, either in a single large dose or in many smaller doses over a long period of time, it does not appear to cause any serious health effects in laboratory animals. It is not known, however, if the same is true in humans. Laboratory animals fed moderate to high

concentrations of lauramide DEA in their diets for three months showed changes in red blood cells, a temporary increase in blood sugar, or a decrease in body weight gain, due to decreased food consumption. A moderate (5%) dose of lauramide DEA in a skin cleanser was repeatedly applied to the skin of laboratory animals for 13 weeks. This dose produced minimal irritation but no evidence of other adverse health effects.

There is no information on whether lauramide DEA can affect the nervous system, produce birth defects, interfere with reproduction, or cause cancer. No interaction of lauramide DEA with genetic material was found in seven studies. One other study suggested that lauramide DEA may interact with genetic material in short-term mutagenicity tests.

Lauramide DEA Environmental Hazard Summary

The environmental hazard summary for lauramide DEA is based on the SAR method described above and in Appendix B. Results (Exhibit 3-2) suggest that lauramide DEA warrants a high level of concern as a hazard to the aquatic environment.

Sodium Laureth Sulfate

Sodium Laureth Sulfate Health Hazard Summary

The information in this summary is taken from CIR (1983).

Sodium laureth sulfate is readily absorbed through the gut after intake by mouth, but is poorly absorbed through the skin. Studies in laboratory animals have shown that most of the sodium laureth sulfate taken by mouth is excreted in the urine, with small amounts appearing in the feces and in exhaled air.

Sodium laureth sulfate has been shown to produce skin and eye irritation at concentrations above 5%. Sodium laureth sulfate applied to the skin of humans or animals produced mild skin irritation. Skin application of consumer products that contained sodium laureth sulfate produced no irritation to severe irritation in humans and animals, depending on the concentration of sodium laureth sulfate in the product. Sodium laureth sulfate did not produce allergic skin reactions when applied to the skin of laboratory animals as a solution in water or when applied to animal or human skin in consumer product formulations. Application of sodium laureth sulfate to the eyes of laboratory animals produced severe eye damage in some animals and no damage in others.

A study of laboratory animals fed diets containing moderate concentrations of sodium laureth sulfate for two years showed no effects except an unexplained weight loss in males. A high concentration of sodium laureth sulfate applied daily to skin with other unspecified substances for 65 days produced severe irritation, hair loss, and death in laboratory animals. At lower concentrations, there were severe skin changes but no deaths.

Studies in laboratory animals suggest that sodium laureth sulfate taken by mouth does not produce birth defects, interfere with reproduction, or cause cancer, and that sodium laureth sulfate applied to the skin does not cause cancer. It is not known if sodium laureth sulfate interacts with genetic material.

Sodium Laureth Sulfate Environmental Hazard Summary

The environmental hazard summary for sodium laureth sulfate is based on the SAR method described above and in Appendix B. Results for sodium laureth sulfate (Exhibit 3-2) suggest that it warrants a moderate level of concern as a hazard to the aquatic environment.

Sodium Lauryl Isethionate (SLI)

SLI Health Hazard Summary

The information in this summary is taken from CCRIS (1995).

Hazard information on SLI is very limited. It is not known how rapidly SLI is absorbed into the body through the gut, lungs, or skin or if SLI is changed into other substances by the body. Available information suggests that SLI may not be a skin irritant and does not interact with genetic material in short-term mutagenicity tests. It is not known if SLI produces birth defects, interferes with reproduction, produces cancer, affects body organs, produces effects on the nervous system, or can produce an allergic response.

SLI Environmental Hazard Summary

The environmental hazard summary for SLI is based on the SAR method described above and in Appendix B. Results for SLI (Exhibit 3-2) suggest that it warrants a moderate level of concern as a hazard to the aquatic environment.

Surfactant Aids

Surfactant aids serve a variety of purposes in the detergent formulation, including builders. These chemicals vary in their potential to cause health and environmental effects. For instance, inorganic phosphates, once commonly used in detergents as builders, are algal nutrients that can cause algal "blooms" (a large increase in algae) in fresh water. The blooms eventually die off, depleting dissolved oxygen in the water; low oxygen levels diminish water's ability to support many forms of life. Substitution of organic chemicals for inorganic phosphates as detergent builders can avoid this problem and offer a better environmental choice.

Acetic Acid

Acetic Acid Health Hazard Summary

The information in this summary is taken from HSDB (1994).

Acetic acid can be absorbed into the body through the gut after intake by mouth and through the lungs of people exposed to acetic acid vapors or mists in air. It is not known if acetic acid is absorbed into the body from the skin. Once in the body, acetic acid is readily changed by the body into other substances.

The dilute form of acetic acid (under 6%) is commonly known as "vinegar." Depending on concentrations, exposure to acetic acid results in various levels of irritation when taken by mouth, inhaled, or applied to the skin. Laboratory animals given strong solutions of acetic acid by mouth showed stomach inflammation and damage. Exposure of human skin to acetic acid may cause ulcers, burns, and inflammation of the skin. Exposure of the skin of animals or humans to high concentrations of acetic acid may produce severe irritation. However, when low concentrations of acetic acid came in contact with the skin of animals, they exhibited no potential for causing irritation. Allergic skin reactions to acetic acid, although rare, have been reported in people. Immediate pain and eye injury have resulted from splashing of a dilute solution of acetic acid into the eye. Permanent eye damage occurred in people whose eyes were exposed to undiluted acetic acid.

Workers exposed to high concentrations of acetic acid in the air have exhibited effects such as inflammation of the lungs, throat, and eyes; erosion of the teeth; enlargement of lymph nodes; swelling of the eyelids; digestive disorders; dry or blackened skin; and swelling of the skin. Animal studies (one to four months in length) in which moderate to high levels of acetic acid were used resulted in weight loss (dermal exposure) and stomach lesions (exposure via drinking water).

One study analyzed pregnant laboratory animals given dilute acetic acid by mouth and found no evidence of birth defects. Available information suggests that acetic acid does not interact with genetic material in short-term mutagenicity tests. However, it is not known conclusively if acetic acid interferes with reproduction in humans or animals.

No direct information was found on the ability of acetic acid to cause cancer in humans or animals. A long-term study in which laboratory animals were fed sodium acetate, a salt of acetic acid, found no evidence of tumors.

Acetic Acid Environmental Hazard Summary

The environmental hazard summary for acetic acid is based on the SAR method described above and in Appendix B. Results for acetic acid (Exhibit 3-2) suggest that it warrants a low level of concern as a hazard to the aquatic environment because after treatment the chemical will be released at pH 7. At this pH the chemical is neutral without acid reaction.

Citric Acid and Sodium Citrate

Citric Acid/Sodium Citrate Health Hazard Summary

The information in this summary is taken from HSDB (1994).

Citric acid is normally produced by the human body and occurs naturally in many foods, such as fruits. It is not known to what extent citric acid or sodium citrate is absorbed through the gut or lungs.

Neither citric acid nor sodium citrate, a salt of citric acid, is expected to be absorbed through the skin. Once in the body, sodium citrate is changed to a different substance and is excreted through the urine.

Citric acid is unlikely to cause harmful effects unless large quantities are consumed. Frequent or excessive intake of citric acid by mouth has produced erosion of tooth enamel, local irritation of the mouth, or ulcers in people. People have reported stomach irritation and stomach disturbances after drinking sodas containing citric acid.

Citric acid can be irritating to the nose, throat, or lungs of people who inhale mists or dusts of citric acid from the air. It can also irritate the eyes or skin if direct contact occurs. Strong solutions of citric acid were a mild skin irritant and severe eye irritant to laboratory animals.

Studies in laboratory animals suggest that exposure to citric acid does not produce birth defects or interfere with reproduction. It is not known from experiments if citric acid produces effects on the nervous system, interacts with genetic material, or produces cancer in humans or animals.

Citric Acid/Sodium Citrate Environmental Hazard Summary

The environmental hazard summary for citric acid/sodium citrate is based on the SAR method described above and in Appendix B. Citric acid and its soluble salts, such as sodium (Na) and potassium (K), at pH 7 are expected to be moderately toxic to green algae in freshwater environments (acute toxicity values are greater than 1 ppm but less than 100 ppm).

The average acute toxicity values for freshwater fish and freshwater aquatic invertebrates are expected to be greater than 100 mg/L.

The most sensitive organism is freshwater green algae, especially in soft freshwater. The average toxicity value (i.e., 96-hour EC_{50} for growth) is expected to be between 3 and 10 mg/L. The chronic value (i.e., the concentration that begins to inhibit the growth of algae) is expected to be between 0.3 and 1 mg/L. At concentrations less than the chronic value, citric acid actually is essential for algae growth. Citric acid is indirectly toxic to algae through over-chelation of nutrient elements necessary for the growth of algae (i.e., citric acid chelate calcium, magnesium, and iron ions) and prevents algae from absorbing enough of these nutrients needed for adequate growth.

In hard water (i.e., hardness equal to or greater than 150 mg/L as calcium carbonate) citric acid is not as toxic. When citric acid is chelated with calcium its toxicity has been mitigated; it is then exposed to algae as the calcium salt and can no longer chelate calcium and other nutrient elements that algae need for growth.

Toxicity of citric acid toward marine algae should be lower than it is for freshwater green algae because of the much higher hardness of sea water as compared to freshwater.

Citric acid has a low potential to bioconcentrate because it is negatively charged and very water-soluble. Therefore, food chain transport should be minimal.

Results for citric acid/sodium citrate (Exhibit 3-2) suggest that it warrants a moderate level of concern as a hazard to the aquatic environment.

Sodium Carbonate

Sodium Carbonate Health Hazard Summary

The information in this summary is taken from CIR (1987).

If sodium carbonate is taken by mouth, it reacts with acids in the stomach to produce carbon dioxide, which is released in expired air. Sodium carbonate can be absorbed into the body through the lungs if it is present in air as a mist, but is not expected to be absorbed through the skin.

It is not known if sodium carbonate is irritating to the mouth or stomach if ingested. Sodium carbonate has been found to be irritating if inhaled or applied to the skin. Laboratory animals that were exposed to mists containing high concentrations of sodium carbonate for a short period of time experienced difficulty in breathing, shortness of breath, wheezing, excessive salivation, swelling of the abdomen, and sometimes death, due to changes or damage to the lungs and respiratory tract. Human skin exposures to bar-soap products containing a low concentration of sodium carbonate resulted in weak irritation but not allergic skin reactions. Application of a high concentration of sodium carbonate to intact skin did not produce skin irritation in people or laboratory animals, but application of the same concentration to abraded skin produced moderate skin irritation in people and one animal species, and tissue destruction in some people. When sodium carbonate was placed into the eyes of laboratory animals, it produced redness often accompanied by a discharge.

Workers who were repeatedly exposed to moderate concentrations of sodium carbonate dusts in air experienced severe skin irritation, skin diseases, eye irritation, and upper respiratory irritation. Damage to the lungs was found in laboratory animals that were repeatedly exposed to low concentrations of sodium carbonate mists.

Studies in laboratory animals suggest that sodium carbonate does not produce birth defects. There is no information on whether sodium carbonate interferes with reproduction, produces cancer, produces effects on the nervous system, or interacts with genetic material in humans or animals.

Sodium Carbonate Environmental Hazard Summary

The environmental hazard summary for sodium carbonate is based on the SAR method described above and in Appendix B. Results for sodium carbonate (Exhibit 3-2) suggest that it warrants a moderate level of concern as a hazard to the aquatic environment.

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